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WATERVILLE LAKE, HAYWOOD COUNTY, NORTH CAROLINA

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH
LABORATORY

PREPARED FOR
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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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NATIONAL EUTROFHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

WATERVILLE LAKE

HAYWOOD COUNTY

NORTH CAROLINA

EPA REGION IV

WORKING PAPER No. 392

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

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REPORT
ON
WATERVILLE LAKE
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WITH THE COOPERATION OF THE

NORTH CAROLINA DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES

AND THE

NORTH CAROLINA NATIONAL GUARD

JUNE, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the North Carolina Department of Natural and Economic Resources for professional involvement and to the North Carolina National Guard for conducting the tributary sampling phase of the Survey.

Lewis R. Martin, Director of the Division of Environmental Management; Darwin L. Coburn, Chief of the Water Quality Section; and Julian R. Taylor, Supervisor of the Monitoring Program Unit; provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

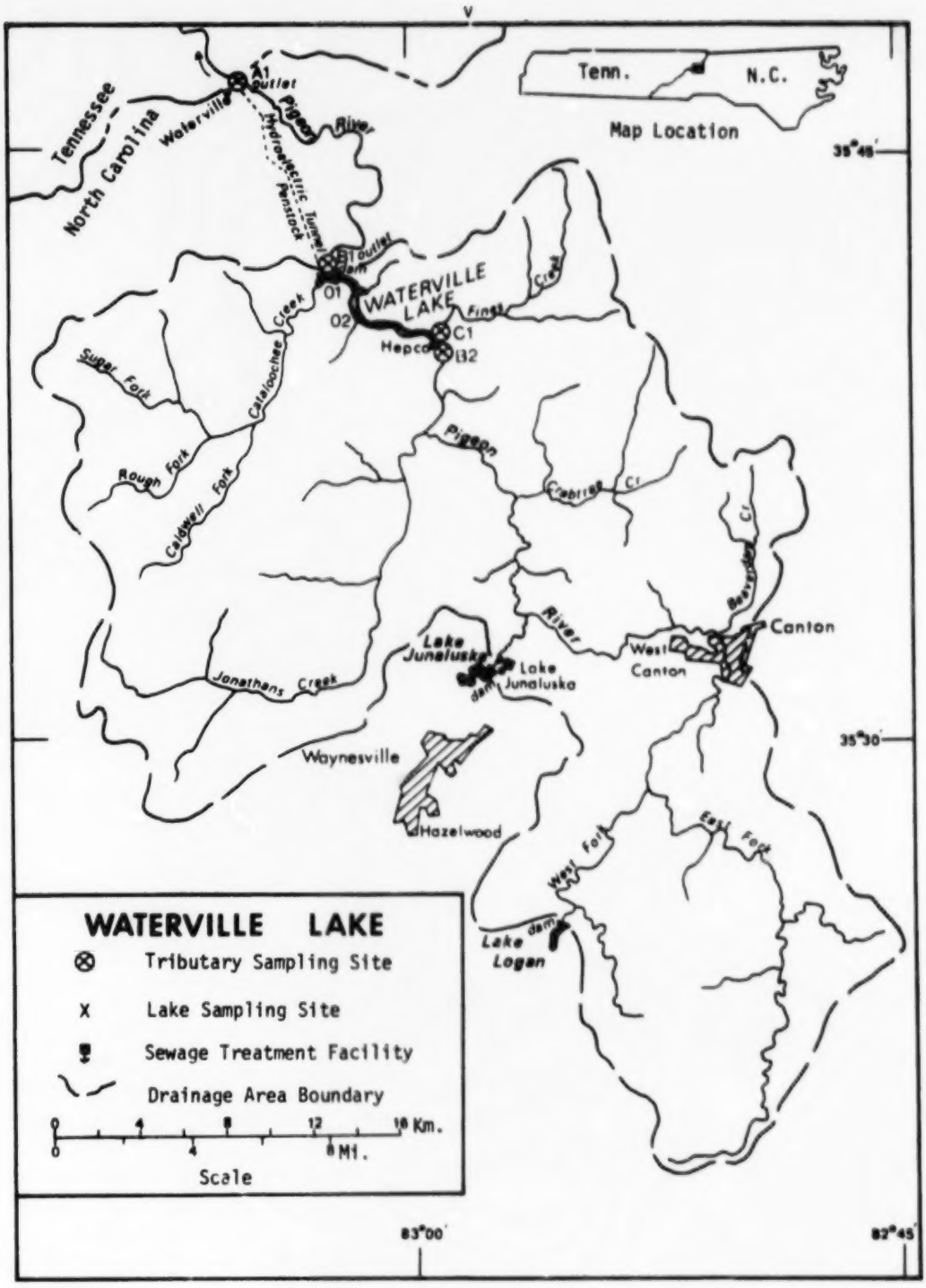
Major General William M. Buck, formerly Adjutant General of North Carolina, and Project Officer Colonel Arthur J. Bouchard, who directed the volunteer efforts of the North Carolina National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF NORTH CAROLINA

LAKE NAME	COUNTY
Badin	Montgomery, Stanly
Blewett Falls	Anson, Richmond
Chatuge	Clay, NC; Towns, GA
Fontana	Graham, Swain
Hickory	Alexander, Caldwell, Catawba
High Rock	Davidson, Rowan
Hiwassee	Cherokee
James	Burke, McDowell
John H. Kerr (Nut Bush Creek)	Granville, Vance, Warren, NC; Halifax, Mecklenburg, VA
Junaluska	Haywood
Lookout Shoals	Alexander, Catawba, Iredell
Mountain Island	Gaston, Mecklenburg
Norman	Catawba, Iredell, Lincoln, Mecklenburg
Rhodhiss	Burke, Caldwell
Santeetlah	Graham
Tillery	Montgomery, Stanly
Waccamaw	Columbus
Waterville	Haywood
Wylie	Gaston, Mecklenburg, NC; York, SC


Tenn.
N.C.
Map Location
35°45'
Tennessee
North Carolina
Waterville
A1 Outlet
Pigeon River
Hydroelectric Tunnel
Penstock
B1 Outlet dam
WATERVILLE LAKE
01
02
C1
B2
Hepco
Cr.
Creek
Catalooche
Sugar Fork
Rough Fork
Caldwell Fork
Pigeon
Crabtree Cr.
Cr.
Beaverdam
River
Canton
West Canton
Lake Junaluska
Lake Junaluska dam
Jonathans Creek
35°30'
Waynesville
Hazelwood
West Fork
East Fork
Lake Logan dam
WATERVILLE LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
0 4 8 12 16 Km.
0 4 8 Mi.
Scale
83°00'
82°45'

WATERVILLE LAKE

STORET NO. 3718

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Waterville Lake is eutrophic. However, since the mean hydraulic retention time of this water body is only 15 days, it more closely resembles a slow-moving stream, and the term "over-enriched" may be a better description of the condition of the lake.

Waterville Lake ranked fourteenth in overall trophic quality when the 16 North Carolina lakes sampled in 1973 were compared using a combination of six parameters*. None of the other lakes had more median total phosphorus, dissolved phosphorus, and inorganic nitrogen; but only three had less mean chlorophyll a. The relatively low chlorophyll a concentrations and high nutrient levels indicate primary productivity probably was light-inhibited. Twelve of the sampled lakes had greater mean Secchi disc transparency, and Survey limnologists commented on the turbid, humic-colored water at both sampling stations each sampling time.

Depletion of dissolved oxygen with depth occurred at station 1 in July and September, and depression occurred at station 2 in July. All dissolved oxygen concentrations were very low in

* See Appendix A.

September; the near-surface sample at station 1 was only 17% of saturation, and the near-surface sample at station 2 was only 25% of saturation.

B. Rate-Limiting Nutrient:

The algal assay results demonstrated nitrogen limitation. However, a differential gain in phosphorus and nitrogen occurred in the assay sample upon autoclaving, and the limiting nutrient was shifted from phosphorus in the lake (mean N/P ratio of 19/1) to nitrogen in the sample (the N/P ratio was less than 12/1). Therefore, the assay results are not representative of conditions in the lake at the time the sample was collected (03/24/73).

The lake data indicate phosphorus limitation at all sampling times. The mean inorganic nitrogen to orthophosphorus ratios were 19 to 1 or greater, and phosphorus limitation would be expected.

C. Nutrient Controllability:

1. Point sources--During the sampling year, known point sources accounted for 18.2% of the total phosphorus load reaching Waterville Lake. The Lake Junaluska wastewater treatment plant contributed 11.8%, and the City of Canton was estimated to have contributed 6.4% of the total load.

The present loading of 93.30 $g/m^2/yr$ is over 19 times the rate proposed by Vollenweider (Vollenweider and Dillon, 1974)

as a eutrophic rate (see page 14). However, the mean hydraulic retention time of Waterville Lake is a rather short 15 days, and Vollenweider's model may not be applicable. Nonetheless, the trophic condition of the lake is evidence of excessive nutrient loads.

Control of phosphorus at the two point sources noted above would be a first step in a program to improve Waterville Lake. However, unless the non-point phosphorus contributions can be reduced significantly, it does not appear that phosphorus removal at the point sources would result in an appreciable change in the trophic condition of the lake.

2. Non-point sources--The phosphorus contribution of non-point sources accounted for 81.8% of the total load during the sampling year. The Pigeon River contributed 68.9%, and Fines Creek contributed 8.8% of this total. Ungaged tributaries were estimated to have contributed 4.1%.

The Pigeon River and Fines Creek had phosphorus export rates of 96 $kg/km^2/yr$ and 170 $kg/km^2/yr$, respectively. These rates are extremely high compared to the rates of the tributaries of nearby Lake Junaluska*; i.e., Richland Creek, 31 $kg/km^2/yr$; Factory Branch, 39 $kg/km^2/yr$; and Unnamed Creek B-1, 28 $kg/km^2/yr$.

* Working Paper No. 384.

The high rate of the Pigeon River may in part be due to underestimation of the phosphorus contribution of the City of Canton and the pulp mill; however, the export rate of Fines Creek was nearly twice that of the Pigeon River, and no known point sources impact the stream. Therefore, it is likely that the high export rates are due in large part to land-use practices in the drainage, but further study is needed to determine this.

Reportedly, tomatoes are the principal crop in the area (Cook, 1975); and, where fertilization is necessary, the culture of tomatoes requires relatively low nitrogen-high phosphorus fertilizers; e.g., a conservative 5% nitrogen-10% phosphorus-10% potassium formulation is sold for use in home gardens. The use of stronger commercial formulations in the area may account for the high export rates noted above.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 1.38 kilometers^2.
2. Mean depth: 22.7 meters.
3. Maximum depth: 54 meters.
4. Volume: 31.2 x 10^6 m^3.
5. Mean hydraulic retention time: 15 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Pigeon River	922.0	19.0
Fines Creek	66.8	1.6
Minor tributaries & immediate drainage -	188.2	3.2
Totals	1,177.0	23.8

2. Outlet -

Waterville Lake hydroelectric tunnel	1,178.4**	24.0
Pigeon River		<0.1

C. Precipitation***:

1. Year of sampling: 146.1 centimeters.
2. Mean annual: 116.6 centimeters.

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† Table of metric conversions--Appendix B.
†† Park, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Waterville Lake was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from a number of depths at each station (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the two stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 39.6 meters at station 1 and 9.1 meters at station 2.

The lake sampling results are presented in full in Appendix D and are summarized in the following table.

SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR WATERVILLE RESERVOIR
STORET CODE 3718

PARAMETER	1ST SAMPLING (3/24/73) 2 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/ 5/73) 2 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (9/20/73) 2 SITES RANGE	MEAN	MEDIAN
TEMP (C)	9.2 - 11.3	10.2	10.1	11.1 - 26.6	22.9	24.0	11.9 - 21.8	20.2	21.3
DISS OXY (MG/L)	9.8 - 10.2	10.0	10.0	0.0 - 7.5	3.9	3.5	0.0 - 4.0	1.6	1.4
CNDCTVY (MCROMO)	120. - 165.	141.	143.	250. - 450.	360.	355.	267. - 735.	657.	713.
PH (STAND UNITS)	7.5 - 7.5	7.5	7.5	6.8 - 8.7	7.4	7.3	6.5 - 7.0	6.8	6.8
TOT ALK (MG/L)	10. - 17.	12.	10.	24. - 61.	35.	33.	57. - 68.	62.	63.
TOT P (MG/L)	0.099 - 0.244	0.127	0.113	0.057 - 0.143	0.093	0.079	0.064 - 0.244	0.104	0.085
ORTHO P (MG/L)	0.036 - 0.051	0.041	0.040	0.019 - 0.082	0.046	0.039	0.034 - 0.056	0.044	0.044
NO2+NO3 (MG/L)	0.610 - 0.670	0.638	0.635	0.350 - 0.870	0.661	0.720	0.070 - 0.630	0.489	0.510
AMMONIA (MG/L)	0.120 - 0.240	0.158	0.155	0.090 - 1.500	0.276	0.140	0.600 - 2.960	1.028	0.830
KJEL N (MG/L)	0.300 - 0.600	0.410	0.400	0.300 - 1.900	0.582	0.480	1.700 - 5.000	2.322	2.000
INORG N (MG/L)	0.750 - 0.870	0.796	0.785	0.440 - 2.300	0.937	0.850	1.220 - 3.030	1.517	1.340
TOTAL N (MG/L)	0.950 - 1.230	1.048	1.035	0.650 - 2.700	1.243	1.120	2.300 - 5.070	2.811	2.560
CHLRPYL A (MG/L)	0.3 - 0.3	0.3	0.3	3.2 - 15.3	9.2	9.2	1.4 - 2.4	1.9	1.9
SECCHI (METERS)	0.6 - 0.8	0.7	0.7	0.6 - 1.0	0.8	0.8	0.9 - 0.9	0.9	0.9

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal units per ml
03/24/73	1. Oscillatoria	422
	2. Blue-green filaments	127
	Total	549
07/05/73	1. Melosira	1,107
	2. Scenedesmus	1,064
	3. Cyclotella	916
	4. Selenastrum	852
	5. Coelastrum	682
	Other genera	2,960
	Total	7,581
09/20/73	1. Flagellates	102
	2. Blue-green filaments	77
	3. Dinoflagellates	64
	4. Scenedesmus	39
	5. Navicula	26
	Other genera	179
	Total	487

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
03/24/73	01	0.3
	02	0.3
07/05/73	01	15.3
	02	3.2
09/20/73	01	1.4
	02	2.4

C. Limiting Nutrient Study:

The control yield of the assay alga, Selenastrum capricornutum, indicated that the potential primary productivity of Waterville Lake was high (control yield = 18.0 mg/l dry weight).

The results also indicated that the sample was limited by nitrogen. However, a 56% gain in orthophosphorus but only a 4% gain in inorganic nitrogen occurred in the assay sample upon autoclaving. The differential gain in these two nutrients resulted in a shift from phosphorus limitation in the lake (mean N/P = 19/1) to nitrogen limitation in the assay sample (N/P = <12/1). Therefore the assay results are not representative of conditions in the lake at the time the sample was collected (03/24/73).

The lake data indicate phosphorus limitation at all sampling times; i.e., the mean inorganic nitrogen to orthophosphorus ratios were 19/1 or greater, and phosphorus limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the North Carolina National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff month of February when two samples were collected. Sampling was begun in March, 1973, and was completed in February, 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the North Carolina District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km^2/year, at station B-1 of nearby Lake Junaluska and multiplying the means by the ZZ area in km^2.

The operator of the Lake Junaluska wastewater treatment plant provided monthly effluent samples and corresponding flow data. The City of Canton

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* See Working Paper No. 175.

did not participate in the Survey, and nutrient loads were estimated at 1.134 kg P and 3.401 kg N/capita/year.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Lake Junalaska	12,000*	prim. clarifier	12,113.3**	Pigeon River
Canton	7,297***	(pulp mill plant)	?	Pigeon River

2. Known industrial -

Name	Product	Treatment	Mean Flow (m^3/d)	Receiving Water
A. C. Lawrence Tannery, Waynesville	leather	(served by Lake Junaluska treatment plant)		
Pulp Mill, Canton	pulp and paper	prim. clarifier	?	Pigeon River

* Treatment plant questionnaire; includes Waynesville, Hazelwood, and Lake Junaluska.
** More than 25% of the total waste load is contributed by industry.
*** Combined 1970 Census of Canton, Philipsville, and Clyde; wastes are treated in the local pulp mill primary clarifier.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (non-point load) -		
Pigeon River	88,650	68.9
Fines Creek	11,375	8.8
b. Minor tributaries & immediate drainage (non-point load) -	5,230	4.1
c. Known municipal STP's -		
Lake Junaluska	15,195	11.8
Canton	8,275	6.4
d. Septic tanks - Unknown	-	-
e. Known industrial -		
Tannery	?	-
Pulp Mill	?	-
f. Direct precipitation* -	25	<0.1
Total	128,750	100.0

2. Outputs -

Lake outlet - Hydroelectric penstock - 63,315
Pigeon River - 125
} 63,440

3. Net annual P accumulation - 65,310 kg.

* See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Pigeon River	833,725	62.2
Fines Creek	110,015	8.2
b. Minor tributaries & immediate drainage (non-point load) -	265,045	19.8
c. Known municipal STP's -		
Lake Junaluska	106,560	7.9
Canton	24,815	1.8
d. Septic tanks - Unknown	-	-
e. Known industrial -		
Tannery	?	-
Pulp Mill	?	-
f. Direct precipitation* -	1,490	0.1
Total	1,341,650	100.0

2. Outputs -

Lake outlet -	Hydroelectric penstock -	919,120	} 921,575
	Pigeon River -	2,455	

3. Net annual N accumulation - 420,075 kg.

* See Working Paper No. 175.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr	N/P Ratio
Pigeon River	96	904	9/1
Fines Creek	170	1,647	10/1

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" rate is the rate at which the receiving water would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m²/yr	93.30	47.33	972.2	304.4

Vollenweider loading rates for phosphorus (g/m²/yr) based on mean depth and mean hydraulic retention time of Waterville Lake:

"Dangerous" (eutrophic rate)	4.80
"Permissible" (oligotrophic rate)	2.40

V. LITERATURE REVIEWED

Cook, Grover, 1975. Personal communication (agriculture in the Waterville Lake drainage). NC Dept. of Nat. and Econ. Resources, Raleigh.

Park, David, 1974. Personal communication (lake morphometry). NC Dept. of Nat. and Econ. Resources, Raleigh.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	3719	LAKE WACCAMAW	534
2	3716	SANTEELAH LAKE	446
3	3711	MOUNTAIN ISLAND LAKE	419
4	3707	HIWASSEE LAKE	414
5	3704	FONTANA LAKE	392
6	3713	LAKE NORMAN	346
7	3708	LAKE JAMES	334
8	3710	LOOKOUT SHOALS	327
9	3715	RHODHISS LAKE	296
10	3705	LAKE HICKORY	283
11	3717	LAKE TILLERY	246
12	3709	LAKE JUNALUSKA	220
13	3702	BLEWETT FALLS LAKE	200
14	3718	WATERVILLE RESERVOIR	140
15	3701	BADIN LAKE	124
16	3706	HIGH ROCK LAKE	76

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
3701	BADIN LAKE	0.042	0.680	466.750	7.190	14.900	0.012
3702	BLEWETT FALLS LAKE	0.090	0.655	476.889	4.167	10.800	0.034
3704	FONTANA LAKE	0.011	0.550	392.650	3.438	14.900	0.007
3705	LAKE HICKORY	0.047	0.320	461.000	7.275	13.400	0.000
3706	HIGH ROCK LAKE	0.090	0.580	477.454	14.283	14.800	0.017
3707	HIWASSEE LAKE	0.015	0.240	420.555	5.678	14.200	0.007
3708	LAKE JAMES	0.020	0.160	428.866	7.660	14.800	0.006
3709	LAKE JUNALUSKA	0.031	0.560	462.000	7.233	14.200	0.009
3710	LOOKOUT SHOALS	0.026	0.370	459.167	4.200	13.800	0.008
3711	MOUNTAIN ISLAND LAKE	0.018	0.270	462.000	5.580	12.800	0.005
3713	LAKE NORMAN	0.019	0.330	446.667	5.807	14.800	0.005
3715	RHODHISS LAKE	0.061	0.305	462.111	3.578	13.600	0.019
3716	SANTEELAH LAKE	0.011	0.160	366.400	5.360	14.800	0.006
3717	LAKE TILLERY	0.040	0.470	468.600	6.827	13.600	0.008
3718	WATERVILLE RESERVOIR	0.103	0.860	468.333	3.817	14.400	0.041
3719	LAKE WACCAMAW	0.018	0.120	455.667	3.583	9.800	0.004

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
3701	BADIN LAKE	33 (5)	7 (1)	27 (4)	27 (4)	3 (0)	27 (4)	124
3702	BLEWETT FALLS LAKE	7 (1)	13 (2)	7 (1)	73 (11)	93 (14)	7 (1)	200
3704	FONTANA LAKE	100 (15)	33 (5)	93 (14)	100 (15)	3 (0)	63 (9)	392
3705	LAKE HICKORY	27 (4)	60 (9)	53 (8)	13 (2)	80 (12)	50 (7)	283
3706	HIGH ROCK LAKE	13 (2)	20 (3)	0 (0)	0 (0)	23 (2)	20 (3)	76
3707	HIWASSEE LAKE	87 (13)	80 (12)	87 (13)	47 (7)	50 (7)	63 (9)	414
3708	LAKE JAMES	60 (9)	87 (13)	80 (12)	7 (1)	23 (2)	77 (11)	334
3709	LAKE JUNALUSKA	47 (7)	27 (4)	43 (6)	20 (3)	50 (7)	33 (5)	220
3710	LOOKOUT SHOALS	53 (8)	47 (7)	60 (9)	67 (10)	60 (9)	40 (6)	327
3711	MOUNTAIN ISLAND LAKE	73 (11)	73 (11)	43 (6)	53 (8)	87 (13)	90 (13)	419
3713	LAKE NORMAN	67 (10)	53 (8)	73 (11)	40 (6)	23 (2)	90 (13)	346
3715	RHODHISS LAKE	20 (3)	67 (10)	33 (5)	93 (14)	70 (10)	13 (2)	296
3716	SANTEELAH LAKE	93 (14)	93 (14)	100 (15)	60 (9)	23 (2)	77 (11)	446
3717	LAKE TILLERY	40 (6)	40 (6)	13 (2)	33 (5)	70 (10)	50 (7)	246
3718	WATERVILLE RESERVOIR	0 (0)	0 (0)	20 (3)	80 (12)	40 (6)	0 (0)	140
3719	LAKE WACCAMAW	80 (12)	100 (15)	67 (10)	87 (13)	100 (15)	100 (15)	534

APPENDIX B

CONVERSIONS FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR NORTH CAROLINA 10/08/75

LAKE CODE 3718 WATERVILLE RESERVOIR

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 1178.4

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
3718A1	1178.4	28.88	34.83	43.04	31.43	22.80	23.08	15.86	16.00	11.47	18.12	18.97	24.64	24.04
3718B1	1178.4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
3718B2	922.0	25.06	29.45	32.00	27.75	19.68	14.87	12.46	12.74	11.04	11.89	13.31	18.83	19.03
3718C1	66.8	2.49	2.66	3.11	2.18	1.47	1.13	1.10	1.13	0.76	0.76	0.99	1.53	1.61
3718ZZ	189.6	4.81	5.24	6.09	4.25	2.97	2.27	2.12	2.27	1.56	1.70	1.98	2.97	3.18

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 1178.4
SUM OF SUB-DRAINAGE AREAS = 1178.4

TOTAL FLOW IN = 286.65
TOTAL FLOW OUT = 289.45

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
3718A1	3	73	64.28	25	56.07				
	4	73	36.53	15	26.31				
	5	73	28.03	23	41.34	27	32.85		
	6	73	31.15						
	7	73	17.56	1	23.98	29	13.17		
	8	73	16.14	12	0.0				
	9	73	9.34						
	10	73	9.63	14	7.08				
	11	73	10.34	10	5.80				
	12	73	32.56	9	26.33				
	1	74	56.35	6	52.67	20	51.82		
	2	74	45.59	10	53.24	24	52.95		
3718B1	3	73	0.57	25	0.03				
	4	73	0.03	15	0.03				
	5	73	0.28	13	0.03	27	0.03		
	6	73	0.03						
	7	73	0.03	1	0.03	29	0.03		
	8	73	0.03	12	0.0				
	9	73	0.03						
	10	73	0.03	14	0.0				
	11	73	0.03	10	0.0				
	12	73	0.57	9	0.03				
	1	74	2.83	6	2.83	20	0.06		
	2	74	5.66	10	0.03	24	0.03		

TRIBUTARY FLOW INFORMATION FOR NORTH CAROLINA 10/08/75

LAKE CODE 3718 WATERVILLE RESERVOIR

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
3718B2	3	73	61.73	25	41.91				
	4	73	32.85	15	26.62				
	5	73	35.68	13	27.47	27	29.17		
	6	73	24.35						
	7	73	14.44	1	16.00	29	12.60		
	8	73	10.19	12	11.04				
	9	73	7.65						
	10	73	6.65	14	6.37				
	11	73	11.19	10	6.09				
	12	73	31.15	9	17.70				
	1	74	45.59	6	51.54	20	24.64		
	2	74	43.61	10	36.81	24	48.99		
3718C1	3	73	4.96	25	2.97				
	4	73	2.21	15	1.70				
	5	73	2.32	13	1.98	27	1.56		
	6	73	1.84						
	7	73	1.19	1	1.42	29	1.13		
	8	73	1.08	12	1.33				
	9	73	0.79						
	10	73	0.57	14	0.54				
	11	73	1.08	10	0.54				
	12	73	2.83	9	1.84				
	1	74	5.38	6	6.51	20	2.55		
	2	74	4.25	10	4.25	24	4.53		
3718ZZ	3	73	9.63						
	4	73	4.25						
	5	73	4.53						
	6	73	3.68						
	7	73	2.55						
	8	73	2.12						
	9	73	1.56						
	10	73	1.13						
	11	73	2.12						
	12	73	5.66						
	1	74	10.48						
	2	74	8.50						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/10/20

371801
35 46 30.0 083 06 00.0
WATERVILLE RESERVOIR
37087 NORTH CAROLINA

11EPALES
3

2111202
0135 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/03/24	10 50	0000	10.4		24	125	7.50	10K	0.120	0.400	0.670	0.038
	10 50	0005	10.3	9.8		120	7.50	10K	0.120	0.300	0.650	0.038
	10 50	0015	9.9	10.0		120	7.50	10K	0.120	0.300	0.650	0.036
	10 50	0050	9.5	10.2		140	7.50	10K	0.170	0.400	0.650	0.040
	10 50	0090	9.4	10.2		145	7.50	10K	0.200	0.400	0.640	0.044
	10 50	0130	9.2	10.0		145	7.50	10	0.240	0.600	0.630	0.038
73/07/05	11 05	0000	25.7		40	360	8.70	34	0.090	0.300	0.350	0.027
	11 05	0005	25.6	7.5		355	8.00	31	0.130	0.400	0.370	0.025
	11 05	0015	24.0	5.1		340	7.30	32	0.160	0.300	0.460	0.036
	11 05	0035	22.9	3.5		355	7.10	33	0.130	0.400	0.660	0.050
	11 05	0065	21.9	3.5		340	7.00	31	0.200	0.400	0.750	0.039
	11 05	0095	20.4	0.9		250	6.80	24	0.150	0.300	0.700	0.019
	11 05	0125	11.1	0.0		285	6.90	61	1.500	1.900	0.800	0.022
73/09/20	12 00	0000	21.4	1.4	36	713	6.80	64	0.830	2.000	0.560	0.044
	12 00	0010	21.3	1.0		703	6.70	63	0.830	1.800	0.500	0.041
	12 00	0030	21.0	0.6		694	6.60	63	0.820	1.900	0.470	0.038
	12 00	0060	19.9	0.6		626	6.70	57	0.780	1.900	0.440	0.034
	12 00	0100	11.9	0.0		267	6.50	68	2.960	5.000	0.070	0.042

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/10/20

371801
35 46 30.0 083 06 00.0
WATERVILLE RESERVOIR
37087 NORTH CAROLINA

11EPALES 2111202
3 0135 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/03/24	10 50	0000	0.103	0.3
	10 50	0005	0.099	
	10 50	0015	0.115	
	10 50	0050	0.111	
	10 50	0090	0.122	
	10 50	0130	0.244	
73/07/05	11 05	0000	0.079	15.3
	11 05	0005	0.063	
	11 05	0015	0.058	
	11 05	0035	0.068	
	11 05	0065	0.062	
	11 05	0095	0.104	
	11 05	0125	0.057	
73/09/20	12 00	0000	0.069	1.4
	12 00	0010	0.064	
	12 00	0030	0.068	
	12 00	0060	0.085	
	12 00	0100	0.115	

STORET RETRIEVAL DATE 75/10/20

371802
35 47 07.0 083 06 48.0
WATERVILLE RESERVOIR
37 NORTH CAROLINA

11EPALES 2111202
3 0035 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/03/24	11 40	0000	11.3		30	165	7.50	12	0.140	0.500	0.630	0.051
	11 40	0004	11.1	10.0		165	7.50	13	0.130	0.400	0.620	0.047
	11 40	0015	10.7	10.0		140	7.50	17	0.170	0.400	0.610	0.043
	11 40	0030	9.9	10.0		145	7.50	17	0.170	0.400	0.630	0.040
73/07/05	12 15	0000	26.6		24	400	7.70	35	0.120	1.000	0.750	0.074
	12 15	0005	26.2	6.3		410	7.70	35	0.110	0.400	0.720	0.076
	12 15	0015	24.7	5.4		450	7.40	33	0.140	0.400	0.870	0.082
	12 15	0030	23.2	3.1		420	7.10	32	0.310	0.600	0.840	0.054
73/09/20	12 40	0000	21.8	2.0	36	734	6.90	63	0.840	2.400	0.610	0.049
	12 40	0010	21.7	1.8		735	6.80	64	0.830	2.100	0.510	0.047
	12 40	0017	21.5	2.6		714	6.80	62	0.760	2.100	0.610	0.047
	12 40	0030	20.9	4.0		728	7.00	58	0.600	1.700	0.630	0.056

STORET RETRIEVAL DATE 75/10/20

371802
35 47 07.0 083 06 44.0
WATERVILLE RESERVOIR
37 NORTH CAROLINA

11EPALES 2111202
3 0035 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/03/24	11 40	0000	0.135	0.3
	11 40	0004	0.133	
	11 40	0015	0.105	
	11 40	0030	0.101	
73/07/05	12 15	0000	0.143	3.2
	12 15	0005	0.127	
	12 15	0015	0.134	
	12 15	0030	0.130	
73/09/20	12 40	0000	0.092	2.4
	12 40	0010	0.084	
	12 40	0017	0.114	
	12 40	0030	0.244	

APPENDIX E

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/10/20

3718A1 LS3718A1
35 46 30.0 083 06 00.0
WATERVILLE LAKE HYDROELEC TUNNEL
37167 7.5 WATERVILLE
0/WATERVILLE LAKE
AT POWER PLANT
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/03/25	11 00		0.590	0.400	0.126	0.050	0.090
73/04/15	13 20		0.390	0.330	0.096	0.027	0.055
73/05/27	14 05		0.430	1.260	0.140	0.036	0.080
73/07/01	13 15		0.530	0.640	0.134	0.039	0.087
73/07/29			0.570	1.150	0.138	0.037	0.095
73/12/04	11 15		0.450	0.700	0.168	0.036	0.085
74/01/06	12 55		0.490	0.200	0.048	0.016	0.055
74/01/20	10 20		0.540	0.400	0.108	0.048	0.070
74/02/10	11 45		0.450	1.400	0.105	0.020	0.065
74/02/24	11 00		0.368	0.600	0.135	0.025	0.145

STORET RETRIEVAL DATE 75/10/20

3718B1 LS3718B1
35 45 30.0 083 02 00.0
PIGEON RIVER
37 MAP HAYWOOD CO
O/WATERVILLE LAKE
BANK 200 FT BELOW DAM
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/03/25	12 25		0.600	0.520	0.220	0.037	0.070
73/04/15	12 30		0.490	0.600	0.200	0.005K	0.100
73/05/13	11 45		0.420	0.900	0.440	0.037	0.100
73/05/27	13 20		0.370	1.000	0.520	0.027	0.070
73/07/01	12 45		0.138	2.200	1.160	0.024	0.110
73/07/29			0.110	2.500	2.500	0.025	0.075
73/10/14	10 40		0.035	4.300	3.200	0.026	0.170
73/11/10	11 00		0.620	3.600	2.200	0.076	0.375
73/12/09	10 30		0.052	4.000	2.200	0.156	0.330
74/01/06	11 45		0.020	3.100	2.200	0.056	0.130
74/01/20	09 45		0.028	4.000	2.670	0.060	0.095
74/02/10	11 15		0.520	0.500	0.075	0.022	0.065
74/02/24	10 15		0.420	1.300	0.520	0.020	0.090

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/10/20

371882
35 40 00.0 082 59 30.0
PIGEON RIVER
37 MAP HAYWOOD CO
T/WATERVILLE LAKE
INT HWY 40 BRDG JUST E OF HEPCO
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/03/25	13 05		0.530	0.720	0.068	0.056	0.135
73/04/15	14 00		0.460	0.690	0.120	0.160	0.270
73/05/13	10 45		0.370	0.915	0.110	0.058	0.195
73/05/27	11 55		0.480	2.300	0.480	0.070	0.290
73/07/01	12 10		0.800	1.800	0.130	0.105	0.210
73/07/29			0.470	0.800	0.105	0.082	0.210
73/10/14	09 30		1.060	1.800	0.198	0.168	0.290
73/11/10	10 15		0.630	1.200	0.176	0.168	0.220
73/12/09	09 15		0.420	0.950	0.100	0.052	0.178
74/01/06	11 15		0.600	0.300	0.070	0.020	0.077
74/01/20	09 05		0.490	0.600	0.085	0.060	0.100
74/02/10	10 45		0.490	0.700	0.035	0.025	0.125
74/02/24	09 15		0.460	0.500	0.070	0.020	0.105

STORET RETRIEVAL DATE 75/10/20

3718C1 LS3718C1
35 40 30.0 082 59 30.0
FINES CREEK
37 MAP HAYWOOD CO
T/WATERVILLE LAKE
ST RT 1338 BRDG 1 MI S OF NEPCO
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/03/25	11 40		1.140	1.200	0.300	0.210	0.330
73/04/15	11 20		0.850	0.270	0.046	0.034	0.060
73/05/13	11 00		0.550	0.290	0.025	0.030	0.070
73/05/27	11 20		0.750	5.600	0.100	0.058	0.170
73/07/01	12 20		0.580	2.310	0.080	0.069	0.120
73/07/29			0.790	1.100	0.023	0.037	0.400
73/10/14	09 40		0.430	1.350	0.153	0.139	0.250
73/11/10	10 20		0.480	0.950	0.096	0.216	0.300
73/12/09	09 45		0.950	1.600	0.252	0.400	0.610
74/01/06	11 20		1.510	0.100K	0.025	0.028	0.095
74/01/20	09 20		1.090	0.950	0.135	0.176	0.330
74/02/10	10 50		1.100	0.300	0.025	0.025	0.065
74/02/24	09 30		1.100	0.400	0.035	0.032	0.090

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/01/20

3718RA PR3718RA P012000
35 31 30.0 082 57 30.0
LAKE JUNALASKA NC
37 HAYWOOD CO HWY M
T/WATERVILLE LAKE
PIGEON RIVER
11EPALFS 21-1204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/05/08	16 00								
CP(T)-			1.000	26.000	11.200	1.050	2.100	3.300	3.200
73/05/08	23 00								
73/06/20	09 00								
CP(T)-			0.622	21.000	2.200	2.000	3.500	3.200	3.100
73/06/20	15 00								
73/08/23	08 00								
CP(T)-			0.620	25.000	4.620	1.780	3.600	2.900	3.100
73/08/23	15 00								
73/10/09	09 00								
CP(T)-			0.480	22.000	9.400	3.790	5.300	2.640	2.500
73/10/09	16 00								
73/11/13	08 00								
CP(T)-			0.390	13.000	4.300	1.150	1.850	0.900	3.100
73/11/13	15 00								
74/01/04	08 00								
CP(T)-			2.400	6.200	1.160	0.670	0.950	3.210	3.200
74/01/04	15 00								
74/03/12	08 00								
CP(T)-				38.000			2.000	3.450	3.200
74/03/12	15 00								
74/04/30	13 00		0.640	36.000	4.800	1.600	2.700	3.500	3.600
74/05/14	00 00								
CP(T)-			0.640	17.000	7.600	3.300	10.000	3.450	3.400
74/05/14	24 00								
74/06/01	08 00								
CP(T)-			0.120	20.000	10.000	1.400	3.000	3.600	3.300
74/06/02	08 00								
74/06/12	08 00								
CP(T)-			0.320	33.000	11.000	1.325	2.700	3.500	3.400
74/06/13	08 00								
74/07/08	10 00								
CP(T)-			0.320	18.000	7.100	1.100	2.300	4.200	3.200
74/07/09	10 00								
74/08/12	13 00								
CP(T)-			0.120	36.000	12.000	2.300	4.000	3.500	3.300
74/08/13	13 00								